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Koomen, E.

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Chapter 12

CONCLUSION AND DISCUSSION

Abstract: This final chapter summarises the most important findings of the preceding chapters and discusses the main methodological improvements of this thesis. The conclusion is centred around the three main research themes: quantifying spatial developments; assessing the impact of spatial policies; and simulating future spatial developments. By way of discussion, the main methodological improvements are highlighted in relation to the issues of: the applicability of very detailed spatial data; the integration of various analysis methods; and the simulation of future land-use changes.

Key words: Spatial analysis; physical planning; methodology; policy implications.

1. INTRODUCTION

The current thesis combines various forms of spatial analysis and many newly available and highly detailed spatial data sets in a series of studies related to different spatial planning issues. These studies relate to both urban and rural areas and they focus on actual physical planning policies as well as some of the policy concepts and general notions that underlie these policies. Besides having a spatial planning focus the presented research also addresses several methodological issues related to data applicability, integration of analysis methods and simulation of land-use changes. The studies forming this thesis centre around three main research themes:

- A. how can spatial developments be quantitatively characterized?;
- B. to what extent do specific spatial policies impact spatial developments?;
- C. how can simulations of future land use support policy makers?

The studies related to quantifying spatial developments (theme A) aim at providing insight in ongoing processes mostly linked to urbanisation as a solid base for policy formulation. These studies have a strong methodological focus as they include many new and highly detailed spatial data sets and various advanced analysis methods including hedonic pricing, self-organizing maps and complex regression analyses. The studies on the impact of spatial policies on spatial developments (theme B), on the other

hand, have a strong policy focus. They, furthermore, relate to predominantly rural areas, as opposed to the more urban orientation of the preceding theme. The studies related to the simulation of future land use (theme C) combine a methodological focus related to the potential merits of current land-use models with an outlook on the policy implications of their results.

The following three sections summarize the outcomes of the presented studies per main research theme, devoting a sub section to each of the ten research questions introduced in Chapter 1. The final section of this chapter then highlights the main methodological improvements in this thesis and discusses possible pathways for further research.

2. QUANTIFYING SPATIAL DEVELOPMENTS

Several studies in this thesis prove that contemporary, detailed spatial data sets in combination with different spatial analysis techniques allow for the quantification of spatial developments. The following sections summarise the findings related to the economic valuing of open space, the quantitative description of urban intensification and concentration processes and the characterisation of land-use diversity.

2.1 Valuing metropolitan open space

The central research question in Chapter 3 is: how can the value of open space be quantified from a city dwellers' perspective? To answer this question the hedonic pricing method is applied to detailed data sets describing house prices and their structural and locational characteristics. This method establishes the added value to residential property of open (non-urban) areas that provide opportunities for rest and recreation.

The estimation results indicate that the availability of local open space (a view of open space and/or the presence of local patches of open space) has a significant positive contribution to house prices. This impact is only found in a relatively short distance range: the added value decreases to zero at a distance of around 50 metres from a house, depending on the case study area. Less conclusive evidence is found about the contribution of larger areas of regional open space to house prices. This may, amongst others, indicate that this essentially regional characteristic is not well-suited to explain local house prices.

The clearly positive impact of local open spaces in the immediate vicinity of houses provides policy makers with additional arguments for the creation of green spaces in new residential areas. The results can, in fact, be used in

discussions about a partial recovery of the construction and maintenance costs for the green spaces that increase the property values.

2.2 Describing urban intensification processes

Chapter 4 addresses the question: how can current urban intensification processes be described? The urban volume indicator proposed here provides an adequate characterisation of the actual physical appearance of the city in time and space. This quantitative description is based on a combination of highly detailed spatial data sets including a 5 metres grid height data set. It allows for an objective, highly detailed analysis of urban patterns in three dimensions.

The potential of this indicator is first tested in a spatio-temporal analysis of the (historic) urban development of the city of Amsterdam. This study shows the gradual lateral extension over the past century as well as the growing importance of numerous high-density zones. The application of the self-organizing map approach underlines these observations and, furthermore, indicates at the recent emergence of small, but extreme high-density developments near stations at a considerable distance from the centre. The urban volume indicator is also applied to spatially compare the four major Dutch cities. This study shows a distinction between cities in which high-density areas are concentrated in the original city centres and cities where these areas are at a considerable distance from the centre. A subsequent statistical analysis indicates that high densities are favoured by the proximity of (intercity) train stations rather than motorway exits.

The urban volume indicator thus helps to visualise and quantify the relative strength of the opposing centripetal and centrifugal forces that shape cities. In this respect it provides useful information about actual urban densities and ongoing urban intensification processes for the debate on urban (re)development. It puts the current discussions on the suggested edge-city type of development into a quantitative perspective, indicating that this process still has a fairly limited impact on Dutch urban morphology. Moreover, the development of high-density zones is related to the presence of (intercity) train stations whose locations, at least in the Netherlands, can be influenced through spatial policies and government investments.

2.3 Characterising urban concentration and land-use diversity

The third research question relates to themes of urban concentration and land-use diversity and aims at finding a method to characterise these spatial

policy issues in land-use maps. This methodology was subsequently applied in a simulation of future land use to answer the question to what extent these policy objectives are likely to be met. Both questions are dealt with in Chapter 9. Here we summarise the methodological results related to the former question. The policy-implications related to the latter question are discussed in Section 4.2.

To select indicators that are effective, they should: 1) relate to the specific policy themes; 2) be intuitively understandable for policy makers 3); capture the essence of the simulation results; and 4) discriminate between different simulation outcomes. The proposed methodology consists of a combination of individual indicators that capture various aspects of urbanisation such as: magnitude (through general composition indices); spatial pattern (grid cell based urbanisation degree); concentration (patch-size distribution); compactness (average urban area circularity); and mixing of land uses (grid cell based diversity indices). The combined use of these composition and configuration indicators at various scale levels makes it possible to unambiguously interpret the projected spatial developments.

The importance of scale-issues in implementing and interpreting indicators can hardly be overstressed. Spatial scale (e.g. grid cell size), thematic scale (e.g. land-use typology) and extent (e.g. study area) are crucial in the application and interpretation of indicators in land-use simulation. The impact of spatial scale is, for example, demonstrated by the urban area size dependency of the presented shape-complexity indicator.

3. ASSESSING THE IMPACT OF SPATIAL POLICIES

Three studies show the extent to which spatial policies impact spatial developments. The first two demonstrate that open space preservation policies have been effective. These studies focus at the national and local level respectively. The third study makes clear that existing spatial policies did not lead to a measurable loss of socioeconomic vitality in rural areas.

3.1 Analysing the effectiveness of national open space preservation policies

The first of the chapters dealing with the impact of spatial policies studies how the effectiveness of open space preservation policies can be assessed at the national level. The presented analysis of transition matrices using detailed land-use data sets covering the full country with a 25 metres

resolution shows that restrictive policies have been relatively effective in limiting urban development.

In the areas where the two different types of restrictive zoning policies apply, the rate of urbanisation has been lower than in non-restricted areas. Urban development was not stopped completely in these areas, but when we realise that urbanisation pressure was above average here, the effectiveness can be considered impressive. The current mitigation of existing restrictive policies related to open-space preservation thus contains the serious risk that municipalities will find more opportunities to allow urbanisation in open spaces. This possible impact is illustrated in Chapter 8.

In many of the restricted areas nature development is the dominant process. This transformation of agricultural land follows national policies that aim at improving ecological values, providing recreational opportunities and preserving the open, non-urban character of these areas. In combination with restrictive policies the stimulated conversion from agricultural land to nature seems to be an effective, albeit costly way to preserve open space.

3.2 Explaining the local success of open space preservation policies

Chapter 6 looks at the effectiveness of open space preservation policies at the local level and wishes to explain how this success became possible. It builds on the GIS-based land-use change analysis of the preceding chapter and looks specifically at the Midden-Delfland area where the Buffer zone restrictions were supplemented with a special Reconstruction Act that governed its land reallocation.

The comparison of land-use changes in this area with changes in other Buffer zones and in the rest of the Netherlands shows that two aims of the Act, the preservation of open space and the development of recreational areas, have been achieved. The activities set out to accomplish the third aim of improving dairy farming conditions have had less impact. As the problems and solutions for this specific agricultural sector stretch beyond the scope of the reconstruction, the general conclusion is nonetheless that combination of restriction and reconstruction has been successful.

In a subsequent, qualitative analysis using in-depth interviews and a policy analysis several clues are offered to explain the success. The tactical idea of developing recreational areas at the urban edges to stop sprawl and the availability of sufficient funds and appropriate institutions were marked by the respondents as reasons for the successful open-space preservation in the area. The presented study suggests that clear restrictive policies that are maintained for prolonged periods in combination with additional instruments

that aim at acquiring agricultural land and strengthening its recreational and natural values are important factors in successfully preserving open space.

3.3 Quantifying rural vitality

Analysing to what extent rural areas are suffering from a loss of socioeconomic vitality is the main question underlying Chapter 7. A GIS-based methodology using a wide range of detailed geographical data sets is applied here to describe the rather vague policy concept of rural vitality. Following a strict socioeconomic interpretation in which housing, employment, demography and level of facilities are considered important indicators, it becomes possible to quantitatively assess the actual state of rural vitality and analyse its development over time.

Based on the selected indicators, small settlements and the surrounding open areas do not seem to perform differently from the rest of the country. From the presented analysis then, it cannot be concluded that the general vitality of the countryside is deteriorating within the investigated period. An initial look at the variation between different regions does not show clear signs that rural vitality is related to a location at the periphery of the country.

The presented findings contradict the current National Spatial Strategy that introduces this policy concept and states that the quality of life and the vitality of various, more rural areas, are deteriorating. In fact, the general spatially non-explicit policies hinted at in the policy agenda and execution program related to the National Spatial Strategy seem to lack a foundation in the observed rural developments. The vitality of the rural surroundings may indeed be at stake at specific locations and for certain socioeconomic groups, but in order to formulate sensible general spatial policies a more precise definition of the problems at hand is needed. The conceptualization of the rural vitality theme described here can provide a starting-point for further discussions on this aspect of the future of our rural areas.

4. SIMULATING FUTURE SPATIAL DEVELOPMENTS

To demonstrate the potential of land-use simulations for policy makers, four studies are presented that support current discussions on: 1) the future of agriculture; 2) policies related to urban concentration and land-use diversity; 3) possible water shortages; and 4) flood risk management.

4.1 Assessing the future of agriculture in the Netherlands

The simulation of future land use performed with the *Land Use Scanner* model in Chapter 8 provides insight into the spatial patterns that may arise under different socioeconomic conditions. These simulations help answer the research question: what future lies ahead for agricultural land in the Netherlands?

The presented scenario study clearly indicates the magnitude of the changes the Dutch countryside is facing. Urban functions and nature are expected to continue to claim agricultural land, but the spontaneous abandonment that, for example, occurs in peripheral areas in Europe is considered highly unlikely as the quality and accessibility of the Dutch land is generally very good. The two opposing scenarios, furthermore, show the possible consequences of the proposed shift from government-driven spatial planning to market-oriented spatial policies. A shift towards less restrictive forms of planning in combination with a strong increase in urban functions could lead to a virtual disappearance of agriculture in parts of the western Netherlands. A mosaic of different types of urban, nature and recreation areas could emerge instead, establishing new park-like landscapes.

A less radical change is suggested by the combination of current spatial restrictions and a moderate increase in urban types of land use. Even the western part of the country then manages to retain a largely agricultural outlook, partially owing to the combination of agriculture and nature conservation. Such are the choices that spatial policy-makers face regarding the future of agriculture in the Netherlands.

4.2 Evaluating future urban concentration and land-use diversity

The land-use simulations introduced in the above-mentioned chapter are also applied to answer the question: to which extent do future land-use patterns meet the current planning objectives of urban concentration and land-use diversity? Chapter 9 tests the potential of the indicators related to the spatial policy themes of urban concentration and land-use diversity already discussed in Section 2.3.

The proposed indicators related to urban concentration clearly mark the differences between the two scenarios. One scenario indicates that a stronger emphasis on economic development combined with less restrictive spatial policies, which are the current aims of the central government, may lead to more extensive forms of urbanisation that could threaten natural and

recreational values. The opposing scenario shows that a continuation of the hitherto prevalent restrictive policies could lead to fewer and larger urban areas than the current situation. In terms of land-use diversity the two scenarios do not perform very differently, but application of this indicator indicates potential 'hot-spots' for mixed land use that can be of great interest to policymakers.

The presented model results are based on a series of assumptions, choices and interpretations and can by no means be considered as an exact prediction of future land-use patterns. The opposing outcomes of the two scenarios do however provide insight in the possible consequences of future socioeconomic conditions and the implications of spatial policy related choices. The results maps also show where these problems are most likely to occur. Therefore, they may be especially useful as a starting point for locally targeted policy measures to counteract expected negative local consequences of general developments and generic policy.

4.3 Analysing future water shortages

Chapter 10 focuses on the question: how can land-use simulations be used to assess possible water shortages in the future? From the two case studies presented here, we conclude that land-use models, such as the *Land Use Scanner*, are adequate instruments to simulate future land-use patterns within a scenario-analysis framework. The applied model proved to be a flexible and open system that allows for the integration of different information sources and the combination with other models for the additional assessment of hydrological impacts.

To facilitate a better integration of *Land Use Scanner* results with the hydrological models it is supposed to feed, a number of improvements has been suggested by the involved hydrological experts. These relate to the level of detail, the land-use typology and the heterogeneous character of the grid cells. The level of detail should preferably be changed from the 500 by 500 metres grid applied in this study to 50 by 50 metres grid cells. The current land-use typology can be improved by adding a distinction in more land-use types with different evaporation characteristics. The final suggested improvement is the output of homogenous grid cells relating to only one type of land use, instead of the current heterogeneous approach that assigns fractions of the cell to a number of land-use types.

The suggested improvements related to the level of detail and the inclusion of homogenous grid cells are included in a renewed version of the *Land Use Scanner*, that has recently become available. The following section discusses an application of this renewed model version.

4.4 Describing the flood-risk impact of spatial safety strategies

The final study of this thesis answers the question how the impact of spatial safety strategies on future flood risk can be assessed. This is demonstrated by the development of a discussion support system (DSS) for water managers that facilitates the debate on different future trends, their impact on flood risk, and the effects of new flood-safety strategies. The DSS follows a scenario approach where the uncertain future is captured in an integrated set of climate and socioeconomic scenarios that permit the assessment of future flood safety and vulnerability to water damage in the Netherlands.

A crucial component in the system is the simulation of future land-use changes according to different scenarios and spatial safety strategies, and based on this, the assessment of future flood risk. The relatively detailed 100 metres grid resolution of the renewed *Land Use Scanner* model makes it possible to perform such calculations on possible future land-use configurations, where these were hitherto limited to more detailed and complex models restricted to the current situation.

The DSS will not exactly predict what will happen nor tell precisely what measurements should be taken, but it acts as a learning instrument that provides insight into possible future developments and some of the options that exist to cope with these projected changes.

5. METHODOLOGICAL IMPROVEMENTS

The preceding sections summarised the most important findings of this thesis in relation to the spatial planning issues referred to in the included studies. The presented research, however, also brings about several methodological improvements that can be related to the subsequent phases of the spatial analysis process (exploration, explanation, simulation, planning support and evaluation) that were introduced in Section 4.1 of Chapter 1. This section discusses the progress in spatial analysis methodology that underlies many of the presented studies and indicates possible pathways for further research. The discussion is organised following the main phases in the spatial analysis process. As a final conclusion the benefits of integrated research methods are discussed.

5.1 Exploration and explanation

A methodological improvement that the exploratory and explanatory studies of Chapters 3 and 4 have in common is the application of highly detailed spatial data. Especially the urban volume analysis shows the enormous potential of high resolution height and other spatial data sets that are currently becoming available in many countries. The increased availability of highly detailed spatial data also benefits the studies related to evaluation and simulation. The availability of detailed data sets in combination with powerful contemporary personal computers, for example, made it possible to increase the resolution of land-use simulation from 500 to 100 metres (Chapter 11).

The potential of highly detailed data sets is not limited to the examples presented in this thesis. It is also present in other data sets that recently became available from such varied sources as the newest generation of remote sensing satellites, large-scale inventories of cadastral institutes, and the tracking and tracing of mobile-phone users. The latter type of data can, for example, be used in the (real-time) monitoring of traffic flows based on the movements of individuals. But also for many other socioeconomic phenomena we are now able to use fine-grained data that allow the exploration and explanation of spatial processes at scales that were unimaginable until recently.

From the presented studies it also becomes clear that such highly detailed data sets offer considerable challenges, especially when it comes to visualising and analysing fine-scaled developments over extensive areas as was the case in Chapter 4. The increased level of detail of newly available data sources, in fact, calls for a rethinking of the methods currently used in exploring and explaining spatial processes, leaving many new research roads open to explore. The provision of highly detailed data essentially allows a shift from more aggregated, cross-sectional research on populations (e.g. neighbourhoods) to more specific research focussed on individual objects (e.g. buildings or persons).

In *exploratory* analysis one of the research issues related to this shift towards micro-level developments concerns the highlighting of small-scale features in extremely large datasets. This visualisation problem is comparable to the finding of a needle in a haystack and calls for visualisation methods that enhance specific features at the cost of others. In Chapter 4 this was done through the application of filtering techniques that highlighted the maximum values in relatively large neighbourhoods.

Apart from demanding faster computers and more efficient programming routines, the use of micro-level data in *explanatory* analysis calls for specific attention to the issue of scale. This is extremely important as different

processes are likely to be dominant at different scale levels. The fact that the value of *regional* open space does not seem to be clearly linked to *local* house prices (Chapter 3) hints at this issue. Besides considering the scale dependency of spatial developments it is also important to take account of the links that exist between different scale levels (Verburg et al., 2004). Chapter 1 (Section 4.2) briefly discussed this issue. The use of micro-level data also allows for a shift in attention from explaining general processes at an aggregated level to analysing the contribution of particular factors to specific processes. This shift in focus is exemplified in Chapter 4 by the analysis of the factors that explain the development of small, high-density zones in urban areas.

5.2 Simulation

The four chapters related to land-use simulation (8-11) present an interesting cross section of recent advances in the development of land-use change models. From the presented studies we can infer a number of observations related to the applicability of this type of instruments in general and the applied *Land Use Scanner* model in particular. These observations relate to: the contradiction of needing detailed results in uncertain situations; the application of the scenario method; the calibration and validation of land-use models and the propagation of errors.

An important contradiction in the application of the *Land Use Scanner* and most other land-use models relates to the need for highly detailed simulations, in terms of both spatial (grid cell) and thematic (number of land-use types) resolution, in long-term studies where many uncertainties exist. Solving this contradiction between the need for local-level detail and large-scale uncertainties regarding future developments is a major task for further research. Interesting related attempts include the construction of multi-scale models (e.g. Veldkamp *et al.*, 2001 or Verburg *et al.*, 2007) and the increased attention for agent-based modelling, as is discussed by, for example, Ettema *et al.* (2007). The scenario method offers a structured approach to deal with the many uncertainties related to future developments, but has some limitations as is discussed below.

Scenario simulation results are heavily reliant on expert judgement, so their validity is questionable. This is inherent to the scenario approach, as is also discussed by Klosterman (1999) in his description of the *What if?* scenario-based planning support system. The limited validity is not a serious problem as long as the simulation outcomes are treated for what they are worth: images depicting possible future developments following a large number of scenario-related assumptions. This guideline for interpreting the results is quite often ignored in subsequent presentation and use of the

outcomes. Devising new ways of presenting uncertain information might help overcome this difficulty.

A way to provide information on the validity of the simulation outcomes is to calibrate and validate the applied land-use models. This provides valuable information about the performance of the models, the relative importance of individual driving forces and the magnitude of current spatial developments, but only applies to the often short calibration periods. The use of such rigorous validation exercises is thus limited for scenario studies dealing with uncertain future conditions that are not necessarily linked to past developments. Scenario analyses therefore need a certain degree of imagination. However, in accordance with Verburg *et al.* (2004), the need is felt to seriously test the capacity of land-use models to produce sensible outcomes. Preliminary validation exercises for the *Land Use Scanner* model have therefore been carried out (Loonen *et al.*, 2007; Loonen and Koomen, 2008; Pontius *et al.*, 2008).

An additional worry for this type of study, which relies on the consecutive use of several models, is the propagation of errors. Initial model results are themselves used as input in a number of subsequent model steps, that each may add extra uncertainties, assumptions and related errors to the original outcomes. This is a well-known issue in GIS (e.g. Heuvelink, 1998) that, however, has received limited attention in the application of land-use models. An initial sensitivity analysis has been carried out for the *Land Use Scanner* (Dekkers, 2005), but more work needs to be done, especially on the consequences of the repeated transformations of model results and the consistency of the scenario-related assumptions in the different models.

5.3 Planning support

Increasing the usability of results is an important issue in the planning-related application of spatial analysis and, more specifically, in land-use simulation models. Options that help presenting, interpreting and comparing modelling outcomes include: the construction of 3D visualisations; the application of interactive presentation media; and the development of indicators that summarise results in relation to policy issues. The implementation of 3D visualisations is beyond the scope of this thesis, but promising research related to the *Land Use Scanner* is underway (Borsboom-van Beurden *et al.*, 2006; Rodríguez-Lloret *et al.*, 2008). The incorporation of interactive or tangible presentation media such as the 'TouchTable' that allows multiple users to view, query and edit geographical information in group sessions is another topic of recent research (Scotta *et al.*, 2006). Application of this device in a spatial planning context has recently started and will be part of further research.

The development of indicators that objectively describe the land-use simulations in relation to specific policy themes was an important element in the preceding three chapters. The assessment of simulation outcomes dedicated to specific themes was considered to be helpful in translating geographical output into meaningful information. These assessments can either be incorporated in the land-use model itself or be executed in subsequent steps in separate models. While the current thesis focussed on developing indicators related to a limited number of policy themes (i.e. urban concentration, land-use diversity, water shortage and flood risk), ample room exists for developing methods to express impacts on a wide range of other themes, including: biodiversity, open-space fragmentation, landscape values and overall space scarcity. An especially interesting policy theme in this respect is the potential for multifunctional land use. This concept is currently receiving a lot of policy attention as a possible solution for solving the land-scarcity problem. Proper incorporation of this concept in contemporary models of land-use change, however, is still in its infancy (Willemen *et al.*, 2007, Van der Heide *et al.*, 2007) and thus demands serious research efforts. Another, hitherto unexplored impact assessment that can be obtained from the presented land-use simulations relates to the issue of spatial inequity. As the model outcomes are available at a fine resolution for the whole country it is fairly easy to distinguish regional differences in terms of, for example, commercial development or the provision of open space. This type of results can be interesting for regional policy makers that want to assess the performance of specific regions relative to others.

A type of planning support that has received little attention in this thesis is the goal-oriented application of analysis and modelling techniques. This normative approach can inform policymakers about possible optimal solutions for spatial planning issues. Chapter 2 hinted briefly at the possibilities of optimisation techniques in land-use modelling and numerous examples of such applications exist. In fact, the *Land Use Scanner* model that is discussed extensively in this thesis has been applied in several studies that aimed at optimising land-use patterns. These applications present different land-use simulations that each follow general scenario conditions and a specific policy objective such as: nature protection, adaptation to climate change and increased accessibility (Borsboom-van Beurden *et al.*, 2007; MNP, 2008). The resulting maps inform policymakers about potential alternative solutions for current spatial problems.

5.4 Evaluation

The main methodological improvement underlying the studies related to evaluation is the increased availability of geographical data that is relevant

to spatial policy themes. *Ex-post* evaluations typically rely on the availability of comparable data sets describing subsequent moments in time. Detailed continuous land-use data sets of different time steps, for example, proved to be important in the studies related to the evaluation of the impact of restrictive spatial policies (Chapter 5 and 6). Whereas the availability of several highly detailed socioeconomic data sets for different time steps, allowed the creation of the time series of vitality indicators presented in Chapter 7. These studies, however, only consider relatively short periods as longer time series of methodologically consistent relevant data sets are not available. Ironically it is the continuous improvement of existing data sources that, partly, causes the observed inconsistencies. For comparative evaluation research the availability of consistent time-series data thus remains a challenging research issue.

The *ex-ante* evaluation of the possible impacts of spatial strategies as presented in Chapter 9 and 11 bypasses this limitation through simulating, rather than observing spatial developments. This approach has, of course, the drawback that it incorporates elements of expert judgement and thus contains a larger degree of uncertainty than the *ex-post* evaluations.

5.5 Integrated research methods

Many of the presented spatial analysis studies rely heavily on the use of GIS and its potential to integrate and analyse data from different sources. Its spatial analytical capabilities allowed, for example, the detailed description of the small settlements and the integration of many different data sets to characterise their vitality discussed in Chapter 7. With the power of contemporary personal computers, it becomes possible to integrate and process the large amounts of spatial and tabular data describing the whole country of the Netherlands. GIS also proved to be an important means to integrate the many different data sources relevant to house prices (Chapter 3) and urban development (Chapter 4).

This thesis also presents a more fundamental level of integration through the combination of different research methods derived from geographical information science, geography, economics and other sciences. This is evident from, for example, Chapter 3 that presents a geographical analysis to process base data for an econometric valuation study. Chapter 4 also combines techniques from different disciplines including new exploratory data techniques typical of GIS and more complex regression analyses. Similarly, the studies into the effectiveness of spatial policies (Chapter 5-7) introduced GIS-based transition matrices and time-series analysis in the realm of spatial planning research, thus adding a quantitative geographical notion to the polemic, often qualitative, planners' discussions on such topics.

The water management related chapters (10 and 11) combine socioeconomic scenario analysis and economics-based land-use modelling with more physically oriented models related to water availability and flood risk. To incorporate notions of causality in the descriptive geographical analysis of Chapters 6 and 7 interviews with stakeholders, more common in social sciences were performed. The importance of thematic and methodological integration is, in fact, also expressed by other researchers in this field (Verburg *et al.*, 2004). Many of the integrated approaches presented in this thesis were, furthermore, only possible through close cooperation within multidisciplinary teams. The presented studies thus clearly advocate the creation of such diverse teams to explore, explain, simulate and evaluate spatial developments in relation to spatial planning.

REFERENCES

- Borsboom-van Beurden, J.A.M., Van Lammeren, R., Hoogerwerf, T. and Bouwman, A. (2006) Linking land use modelling and 3D visualisation; a mission impossible? In: van Leeuwen, J.P and Timmermans, H.J.P. (eds.) *Innovations in Design & Decision Support Systems in Architecture and Urban Planning*, Springer, the Netherlands, pp. 85-101.
- Borsboom-Van Beurden, J., Bakema, A. and Tijbosch, H. (2007) A land-use modelling system for environmental impact assessment. Chapter 16 in: Koomen, E., Stillwell, J., Bakema, A. and Scholten, H.J. (eds.) *Modelling land-use change; progress and applications*, Springer, Dordrecht, pp. 281-296.
- Dekkers, J. (2005) *Grondprijzen, geschiktheidkaarten en parameterinstelling in de RuimteScanner. Technisch achtergrondrapport bij Ruimtelijke Beelden*, RIVM report 550016005, Bilthoven.
- Ettema, D., De Jong, K., Timmermans, H. and Bakema, A. (2007) PUMA: multi-agent modelling of urban systems. Chapter 14 in: Koomen, E., Stillwell, J., Bakema, A. and Scholten, H.J. (eds.) *Modelling land-use change; progress and applications*, Springer, Dordrecht, pp. 237-258.
- Heuvelink, G. (1998) *Error Propagation in Environmental Modelling with GIS*, Taylor & Francis, London.
- Klosterman, R.E. (1999) The What-If? collaborative planning support system, *Environment and Planning B* 26: 393-408.
- Loonen, W. and Koomen, E. (2008) *Calibration and validation of the Land Use Scanner allocation algorithms*, Milieu- en Natuurplanbureau, Bilthoven (forthcoming).
- Loonen, W., Koomen, E. and Kuijpers-Linde, M. (2007) *Calibrating and validating the Land Use Scanner algorithms*, paper presented at the 15TH European Colloquium on Theoretical and Quantitative Geography, September 7-11, 2007, Montreux, Switzerland.
- MNP (2008) *The Netherlands in the future; Second Sustainability Outlook: the Netherlands physical living environment*. Netherlands Environmental Assessment Agency (MNP), Bilthoven, (forthcoming).
- Pontius Jr., R.G., Boersma, W.T., Castella, J-C., Clarke, K., De Nijs, T., Dietzel, C., Duan, Z., Fotsing, E., Goldstein, N., Kok, K., Koomen, E., Lippitt, C.D., McConnell, W., Pijanowski, B.C., Pithadia, S., Sood, A.M., Sweeney, S., Trung, T.N., Veldkamp, A. and

- Verburg, P.H. (2008) Comparing the input, output, and validation maps for several models of land change, *Annals of Regional Science* 42 (1): 11-37.
- Rodríguez-Lloret, J., Omtzigt, N.O., Koomen, E. and De Blois, F.S. (2008) 3D visualisations in simulations of future land use: exploring the possibilities of new, standard visualisation tools, *Journal of digital Earth* 1 (1): 148-154.
- Scotta, A., Pleizier, I.D., Scholten, H.J. (2006) Tangible user interfaces in order to improve collaborative interactions and decision making. In: Fendel, E., Rumor, R. (eds.) *Proceedings of 25th Urban Data Management Symposium* (UDMS 2006) 15-17 May, 2006, Aalborg, Denmark, Urban Data Management Society, Delft.
- Van der Heide, C.M., Overmars, K. and Jongeneel, R. (2007) Land use modelling for sustaining multiple functions in the rural countryside with an application in the Achterhoek Region, the Netherlands. In: Mander, Ü, Wiggering, H. and Helming, K. (eds.) *Multifunctional land use; meeting future demands for landscape goods and services*, Springer Verlag, Berlin, pp. 251-268.
- Veldkamp, A., Verburg, P.H., Kok, K., de Koning, G.H.J., Priess, J. and Bergsma, A.R. (2001) The need for scale sensitive approaches in spatially explicit land use change modelling, *Environmental Modeling and Assessment* 6: 111-121.
- Verburg, P.H. and Overmars, K.P. (2007) Dynamic simulation of land-use change trajectories with the CLUE-s model. Chapter 18 in: Koomen, E., Stillwell, J., Bakema, A. and Scholten, H.J. (eds.) *Modelling land-use change; progress and applications*, Springer, Dordrecht, pp. 321-335.
- Verburg, P.H., Schot, P.P. Dijst, M.J. and Veldkamp, A. (2004) Land use change modelling: current practice and research priorities, *GeoJournal* 61: 309-324.
- Willemen, L.L.J.M., Verburg, P.H., Hein, L.G., Van Mensvoort, M.E.F., Veldkamp, A., Leemans, R. (2007) Spatial characterization of landscape functions in a multifunctional rural region. In: Addink, E., Barendregt, A., Ettema, D., Karssenbergh, D. and De Nijs, T. (eds.), *Framing Land Use Dynamics II - abstractbook International conference*, 18-20 April 2007, Utrecht University, the Netherlands.